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ABSTRACT

Modern psychological theory implies that behavior and neural function are correlated. Models of the operation of the nervous system can be used to predict and explain behavioral events. The purposes of this paper are to briefly outline a model at the biopsychological level that leads to predictions about the retention of verbal material, to show from the research that such predictions are confirmed, and to suggest some educational applications that might improve the retention of written and verbal material. (RE)

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Abstract

EDUCATIONAL IMPLICATIONS OF A BIOPSYCHOLOGICAL MODEL OF LEARNING

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Modern psychological theory implies that behavior and neural function are correlated. Models of the nervous system's operation can be used to predict behavioral events. However, little attention seems to have been directed toward making decisions about how to control learning in educational settings based on neurological assumptions.

Hebb (1966) and Landauer (1969) hypothesized the existence of consolidation processes, where consolidation refers to the creation of relatively permanent changes in the nervous system that underlie learning, which would indicate that a new definition of reinforcement is desireable in psychology and education. A definition posed by Estes (1960) appears useful where he "identifies reinforcement empirically with the operation that is supplied by the experimenter in order to produce learning." In this way such things as repetitions and test items could be considered reinforcers. The use of such things as repetitions and test items could be used in the educational setting to function as reinforcers in learning.

Research in a number of areas has demonstrated that such suggestions appear to be useful. Research in paired associate learning (PAL) (Allen, Maher & Estes, 1969; Landauer, 1969; Landauer and Eldridge, 1967; McAllister and Ley, 1972) and prose learning (Frase, 1967, 1968; Rothkopf, 1966; Rothkopf & Bisbicus, 1967) both indicate that the use of test like items and repetitions, appropriately spaced, result in increased retention of the verbal material.

Extending the model to the educational setting, modifications in classroom lectures, textbooks, and programmed intruction may prove to be desireable.

In summary, biopsychological models of learning can be used to stimulate innovations in the educational system. First, the theories would suggest appropriate research studies to be carried out and if the data support the theory, then appropriate educational applications could be instituted. It would seem that serious consideration should be given to biopsychological models by the educational community.

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Educational Implications of a Biopsychological Model of Learning

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(Presented at the Annual Meeting of the Northeastern Educational Research Association, Ellenville, New York, 1973)

Modern psychological theory implies that behavior and neural function are correlated. Models of the operation of the nervous system can be used to predict and explain behavioral events. It appears that such models have been neglected in designing applications of learning theory to educational practice. The purposes of this paper are to briefly outline a model at the biopsychological level that leads to predictions about the retention of verbal material, to show from the research that such predictions are confirmed, and to suggest some educational applications that might improve the retention of written and verbal material.

The model is, in essence, an extension of Hebb's (1949, 1966) neurophysiological model of learning. The basic idea stems from Hebb's proposal that an experience allows the formation of an active circuit in the brain which outlasts the experience but still decays rather quickly. The temporary activity is assumed to promote structural changes which carry permanent representations of the event. Hebb (1966) states:

> "From our present knowledge one may guess that the consolidation process is either or both of two things: a structural change at the synapse,

or a biochemical change in the two neurons concerned.

"The structural change would involve synaptic knobs: A new knob develops, or an existing knob grows bigger, or it grows closer to the receiving dendrite or cell body. Actual synaptic transmission is chemical, the knob secreting some exciting substance (it is known to be acetylcholine at some synapses) each time an impulse reaches it. Obviously a closer or more extensive contact increases the probability that the substance will have an effect. The time needed for such structural growth would be the consolidation period.

"However, since synaptic transmission is chemical, another possibility is that consolidation consists of a biochemical change in one or both neurons, again with the results that A can excite B more readily. Such a biochemical process might also take the half-hour or so that is needed for consolidation. (The term consolidation refers to the formation of a lasting neural change (anatomical or chemical) which represents learning). Recently all attention has been directed to the chemical hypothesis of memory -- that is, of synaptic changes and consolidation -- and indeed there is evidence to support it. But the structural hypothesis has not been ruled out, and at least it has the advantage that we can see how it would work. For the present, either or both can be entertained; accepting one does not rule out the other."

Landauer (1969) in his theory adds a few assumptions:

1. "While the reverberatory trace remains active an ordinarily ineffective input may reinstate part or all of the neural activity originally initiated by the events of a learning trial."

2. "Additional consolidation of the long-term trace, and thus additional reinforcement could be obtained by virtue of an input other than a complete repetition of the learning trial events themselves, provided that this input occurred soon enough after the trial." (a "virtual trial")

3. "Primary features of reinforcement of this sort would be that (a) reinforcement would be retroactive, and (b) what is reinforced would depend only on temporal contingency."

4. "The state of the system following a trial is such that two closely succeeding activations will not produce twice as much consolidation as one. In other words, the consolidation induced by two identical events is assumed to be less that fully additive if they occur too closely together."

Based on the above assumptions, Landauer's (1969) theory views "All reinforcers as special cases of a single phenomenon, namely, the provision of opportunity for consolidation of a new neural organization." It appears thattwo factors are involved, i.e., the probability of reinstatement and the effectiveness if reinstated. The probability that a reinstatement of neural activity can occur continually decreases as a function of increasing time (see Figure 1). However, simultaneously

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Insert Figure 1 about here

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the neural activity itself decreases and if the activity is reinstated, its value for consolidation increases. Figure 2 shows the effect of a "reinforcement" when it reinstates the

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Insert Figure 2 about here

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the neural activity. The shaded area shows the net gain in neural activity as a result of the reinforcement. If the neural activity could still be reinstated at a later time when the activity had approached zero, the net gain in activity due to "reinforcement" would be greater that if the reinstatement had occurred earlier (see Figure 3). Again the shaded area shows

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Insert Figure 3 about here

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the net gain in activity resulting from the "reinforcement." If the "reinforcement" was not able to reinstate the neural activity, it would be necessary to use a repetition of the original learning trial to do so. Figure 4 shows such an event. The shaded area shows the net gain in neural activity

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Insert Figure 4 about here

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resulting from a repetition of the learning trial. It can be seen from these diagrams that according to the theory what has been called a "delayed reinforcer" approximates the effectiveness of a second learning trial if the neural activity can be reinstated. The Hebb-Landauer explanation assumes that the added neural activity furthers the consolidation of the neural trace which in turn results in better retention. The "delay of reinforcement" curve is generated as a product of the probability that neural activity can be reinstated and the gain in neural activity if there is reinstatement. Figure 5 shows this

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Insert Figure 5 about here

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curve. Under this particular model, "reinforcers" act by producing a partial equivalent of an extra trial. The delay of reinforcement" curve shows that "reinforcement" should be

most effective at an intermediate delay interval where the "reinforcer" can still reinstate neural activity and at a point where the reinstatement is valuable. Therefore, the model explains the basic "reinforcement" phenomenon under the assumption of reinstatability. The spacing phenomenon in learning is explained by the non-additivity of two overlapping events that induce consolidation. That is, there is a maximum "neural activity point" beyond which neural activity normally does not pass. Reinstating neural actvitiy immediately gives very little net gain since the neural activity is already near its maximum. However, since the neural activity continually decreases, a delayed reinstatement results in a greater gain than the immediate reinstatement. This can be seen diagrammatically in Figures 2 and 3. The delay-retention effect (DRE) can be explained under a combination of these assumptions. "Reinforcers," then, are any phenomena that can reinstate the neural activity leading to consolidation (Landauer, 1969).

Landauer's (1969) theory predicts that there is a time after the inital learning trial in which an ordinarily ineffective event can improve retention. The time interval is determined by the rate of decay of the neural activity which was set up in the initial learning trial and the probability of reinstatement.

A number of experiments have been carried out manipulating various spacings of repetitions of various test items and measuring the effect on the retention of the material. These repetitions

or test items could be considered reinforcers in the sense that there is a strengthening of a change in a behavioral tendency (Landauer, 1969). Such a view broadens the concept of reinforcement so that all reinforcers are viewed as "special cases of a single phenomenon, namely, the provision of opportunity for consolidation of new neural organization" (Landauer, 1969).

Experimental evidence in support of the theory was obtained by Landauer and Eldridge (1967) in a series of studies. The experiments investigated the effect of intralist test items without feedback in PAL in terms of matching or multiple choice tests after retention intervals. Ths Ss for Experiment I were 108 3-5 year old nursery school children. A set of cards was prepared showing eleven different color drawings of boys and girls. Each picture was assigned a name, avoiding the names of the Ss. The Ss were presented with 17 cards. Six were duplicates of ones earlier presented. Of these six, three were repeated immediately following their initial presentation and the other three were repeated after two or three other cards had intervened. The cards were presented at a 5 second per card rate. For Ss in the pair-pair group the second presentation was like the first. For the other half of the Ss, the pair-test group, only the original presentation was accompanied by a name. Second presentations were "tests" in which the subject was to provide the name. No feedback was given. Following the one learning trial, Ss were allowed to play for two minutes and then a matching test was given.

The results showed no significant difference between the two groups. Tests without feedback are equally as effective as repeated presentations. Significant differences were found in each group in favor of the "spaced" presentations over the "massed" presentations. In Landauer and Eldridge's (1967) Experiment II, intralist tests were spaced with 0, 3, and 11 intervening items. This spacing necessitated longer lists. The Ss were forty 14 and 15 year old junior high school students. Two sets of materials were used: an expanded set of 18 different children's pictures and a set of 18 Chinese characters. Each subject was presented 30 cards. On the first trial, the experimenter supplied the name of the child or Chinese symbol. On the second trial the experimenter asked for the name and supplied no feedback. Retention was determined after 10 minutes. In the picture-name set, the improvement with a short delay (3 seconds) and a decrease with longer delays were found. No significant differences were found in the Chinese noun set.

Experiment III employed the more common verbal PA task with a recognition test. The Ss were 60 Stanford students. A memory drum was used with 40 PA items in which the stimuli were randomly selected two digit numerals and the responses were adjectives. Twenty-four pairs served in the experimental conditions and 16 pairs served as buffers. The retention effect was tested after 5 minutes. The presentation intervals were 0 and 3 items. The results showed that tests without feedback again appear to facilitate memory. However, in this experiment

immediate tests appear to be more beneficial than separated pairs.

In summary the Landauer and Eldridge (1967) study indicates that recall tests without feedback may improve learning as measured by later recognition tests. Secondly, the effectiveness of the intralist test item depends on the interval size. It appears that the nature of the material learned is associated with differences in the delay retention effect.[1]

Landauer (1969) reports further supporting experimentation. In one experiment four 12-pair lists were constructed of varying stimuli and responses. (Nonsense syllables-numerals, body parts-colors, adjectives-consonants, and first names-month). Intervals were 0, 1, 3, and 5 items. The Ss were 167 students in an introductory psychology class who were treated in a group. The Ss turned through the booklet at a 2.5 seconds per page rate. Retention tests were given 3 minutes following initial presentation. A second test was given 3 days later. A strong relationship between spacing over intervals and the amount of learning produced by the second presentation was found.

Landauer (1969) reported two further experiments which clearly show the non-monotonic function of the delay gradient. In Experiment I (done with Rubin) 378 students in an introductory

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1. Earlier studies had shown a similar effect but had not been viewed from this particular framework. (See Peterson, Wampler, Kirkpatrick, & Saltzman, 1963; Greeno, 1964; Cofer, Diamond, Olsen, Stein & Walker, 1967; and Allen, Mahler, & Estes, 1969).

psychology course learned a 36-item PA list. Seven pairs were presented twice in a pair-pair form. A second seven items were presented twice in a pair-test form for the second presentation with no feedback. Intervals of 0, 1, 2, 4, 8, 12 and 16 items were used between the first and second presentations. Sixteen different orders of the list were used. The retention test following the learning trial by 20 minutes.

The results showed the "non-monotonic function for later recall of items tested at varying intervals during the learning trial." Significant differences were found between 0 and 1, and 2, 0 and 4 interveing items for the pair-test PAs during the learning trials. The decline over intervals is also statistically significant. Tests with 1, 2 or 4 intervening items produced significantly better recall than did single presentation while tests after intervals of 0, 8, 12, or 16 intervening items produced non-significant difference over single presentations.

In Experiment II (done with Butler) Landauer (1969) ran an experiment similar to that described above. The Ss were 128 undergraduates from San Fernando Valley State College. The results showed that the number of correct responses on the intralist tests decreased as the interval size inccreased while the proportion correct on the retention test increased as interval size increased. Landauer (1969) concludes:

> "Perhaps the most active issue in reinforcement theory has been the question of how to predict that an event will or will not act as an operant reinforcer. As

> stated above, the present theory is not principally directed towards this issue, but rather towards the mechanism by which the effect might occur. However, it is hypothesized that reinforcing events have the property of reinstating recent neural activity and this reinstated activity might be expected often to be accompanied by an overt response... In fact, it was just such a property which prompted the prediction that a test item would work as a reinforcer in paired associate learning, provided it was given at an appropriate time following an initial trial."

McAllister and Ley (1972) tested the effects of reinforcement type (stimulus test term, response test term, and stimulus-response pair repetition), delay of reinforcement interval, presentation rate, and meaningfulness in PAL. The Ss were 228 undergraduates at Russell Sage College. Each treatment list was made up of 37 different PAs with 15 receiving appropriately spaced test items or repetitions. The results showed that delayed reinforcers (test items and repetitions) resulted in greater retention than their respective immediate reinforcers for high meaningfulness material. In addition, the results indicated that the delay of reinforcement gradient is a function of the number of intervening items during the delay and not amount of time. Finally results showed that repetitions were superior to test items in fostering retention. These basic findings were replicated by McAllister (1973).

Would similar results be found in more complex learning? Although the theoretical approach is different, it appears that such findings do indeed exist. Some research at the Bell

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Telephone Research Laboratories has been investigating the use of questions in more complex verbal learning. It is interesting to note that the results are, in general, in harmony with the paired associate research already mentioned. Rothkopf (1966) found that test questions presented after a text passage have both specific and general facilitative effects on post-reading performance. He further states:

> "Test-like questions, which were presented before the relevant text passage was read produced only question-specific facilitative effects. These question-specific effects were greater when the correct answer was given to the student after he made his response than when no knowledge of results was available. However, even without knowledge of results, the specific trainings effects which resulted from exposure to the experimental questions (after the text passage) were very marked."

Rothkopf and Bisbicus (1967) investigated the use of restricted categories of questions, incorporated in written instructional material to determine if retention of restricted categories of text content was improved. They found that retention, as measured by a post-training test was facilitated by appropriate questions seen after exposure to relevant text sections. Questions placed before the segments were not found to produce any facilitation.

Frase (1967), using college students as subjects, investigated the effects of position of factual questions within the text, length of passage, and presence of knowledge of results on the retention of prose material. He tested subjects on both "incidental" material (material not dealt with

by intraprose questions) and 'retention' material (material dealt with by intraprose questions). The results showed that all 3 factors were signficant for "retention" questions and only the position of the questions was significant for the "incidental" questions. Questions placed after the prose passages resulted in optimum performance for both specific and general retention.

Frase (1968b) studied the effect of question location, question pacing, location of relevant content, and question mode upon the retention of "relevant" and "incidental" material. The results again showed that retention was greatest when questions were placed after paragraphs.

Frase (1968a) used questions that were designed to get subjects to respond to relatively small or large amounts of material. However, the general questions did not work the way that was expected from the more specific questions used in previous studies. Frase (1968c) states that "there seems to be an optimal distance between the questions and the related material for maintaining both the selective and facilitative effects of questions across a range of motivational conditions."

The findings of Rothkopf and Frase, mentioned above, are very similar to the findings found in the paired associate studies. The major problem is that in prose material control over the delay interval is not very exact. The results of these studies clearly showed that immediate repetitions and immediate test items were not as effective in fostering

retention as were delayed repetitions and delayed test items. Restricting the discussion momentarily to repetitions, a theoretical implication would seem that the Landauer (1969) consolidation theory might generate useful hypotheses regarding the question of distributed practice. A theory such as the Landauer (1969) theory would predict that distributed practice would be superior to massed practice. However, this would be true only if the distributed practice were arranged in certain ways. That is, the theory predicts that benefit will be derived from intermediately delayed repetitions if and only if they are positioned in such way so as to provide reinstatement of the neural activity. Distributed practice that arranged the repetitions in such a way so that the delay interval does not allow reinstatement would not be significantly better than massed practice. It would seem that manipulations such as these would be extremely useful for some further research.

A second implication is related to the aspect of massed and distributed practice but not restricted to only repetitions. Landauer (1969) pointed out that the issue of whether the decrease in neural activity was related to some activity or just time passage was not at issue in his discussion although it was of interest. The results found by McAllister and Ley (1972) gave preliminary indications that the delay of reinforcement effect is not simply a function of the passage of time. The effect appeared to be related to the number of items intervening and even to the kind of item intervening.

This certainly was a major implication that will need to be considered for predictions from the theory and opens up a need for a program of further research.

Some other implications result from the experiments. The experiments showed that delayed reinforcers are superior to immediate reinforcers in terms of retention measures. An immediate question involves the claims regarding immediate reinforcement in programmed instruction. This is an area in which research is needed. It might very well be that a structural modification in programs to make use of delayed reinforcement might provide for better retention of the material. The problem seems to have been that there has been much more concern with the relationship of programming to acquisition but not to retention. This retention question, however, cannot be ignored and some experimentation should be carried out.

Another application is the need to look into the question of making use of delayed reinforcement (repetitions or test items) in prose material and in teaching behavior. Modifications may be made in the format of textbooks, for example, to foster better retention of the material that the student reads. Chapters should be arranged so that questions followed after a specified number of lines or after every paragraph. Such modifications would make textbooks quite different than they are presently and may even influence the reading process itself.

It may also be that application can be made in the technique of lecturing. The use of delayed test items and

repetitions during a lecture may be a distinct possibility that can be used to foster the retention of verbal material that is spoken. It would be very interesting to see if the same results appear under these conditions. One possibility in this area might be an experiment in which the PAs are arranged as in this experiment but are spoken so that the subject hears rather than sees the material.

In summary, it appears that starting from a biopsychological model predictions can be generated regarding behavior. These predicted behavioral phenomena can be tested by appropriately designed research studies. If the results of the research confirm the predictions generated by the model, then applications can be designed appropriate to educational practice. Such applications derived from the biopsychological model and supported by experimental results in a more basic format can then be instituted and tested in the applied educational setting. It is not the purpose of this paper to suggest that researchers and innovators in education should restrict themselves to biopsychological models but only to point out that currently such an approach could contribute, along with other theoretical orientations, to educational practice.

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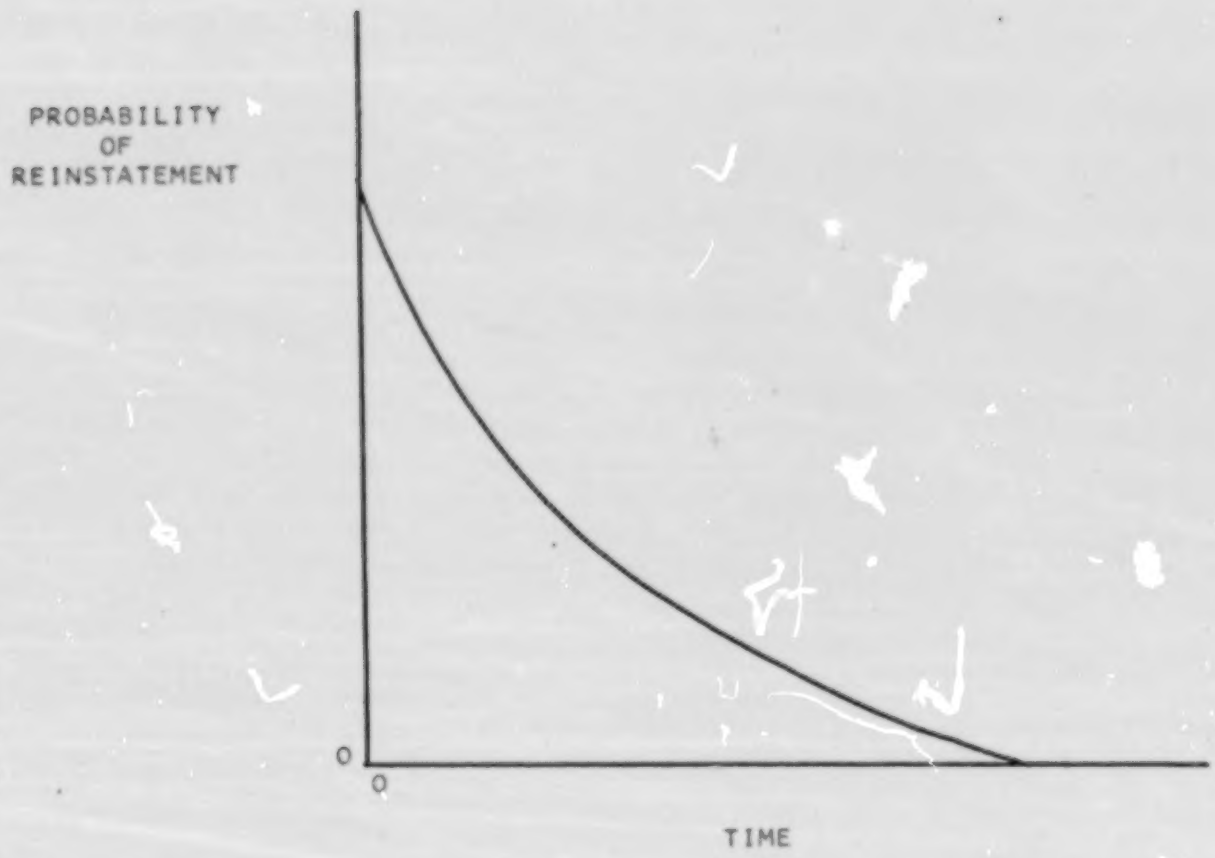

FIGURE 1. PROBABILITY THAT NEURAL ACTIVITY CAN BE REINSTATED

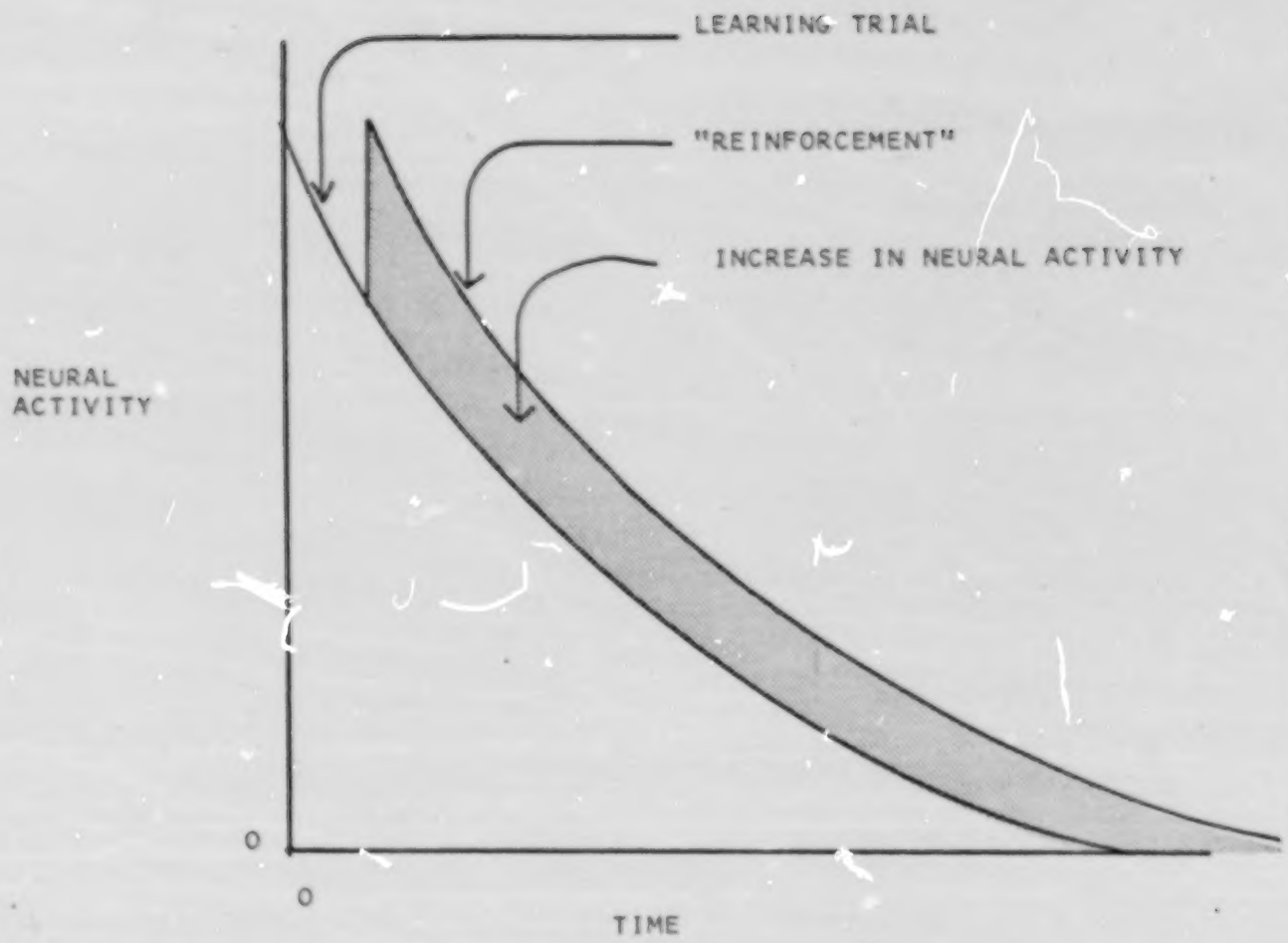

FIGURE 2. EFFECT OF A "REINFORCEMENT" INTERMEDIATE DELAY (AFTER LANDAUER, (1969)

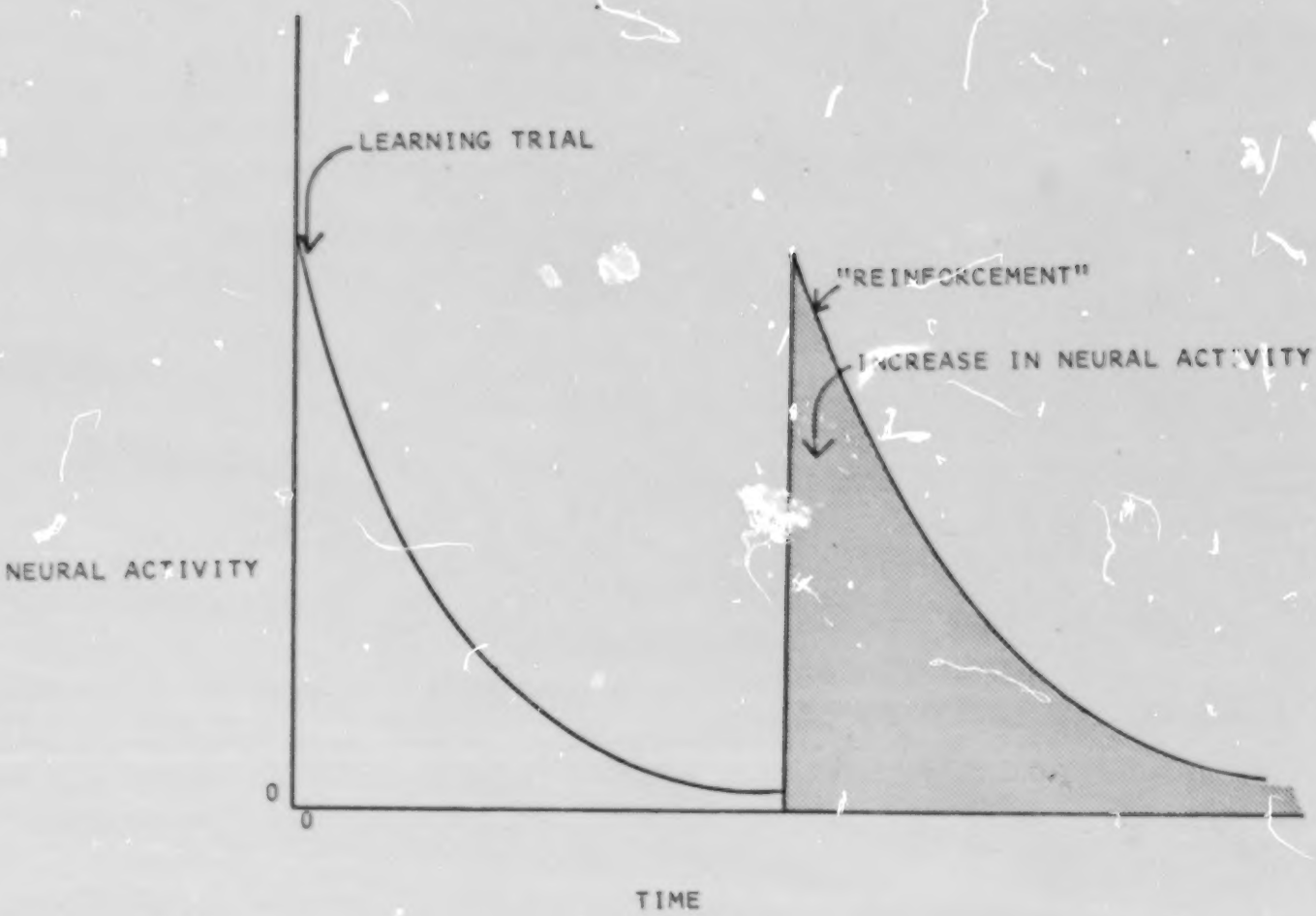

FIGURE 3. EFFECT OF "REINFORCEMENT" EXTENDED DELAY (AFTER LANDAUER,(1969))

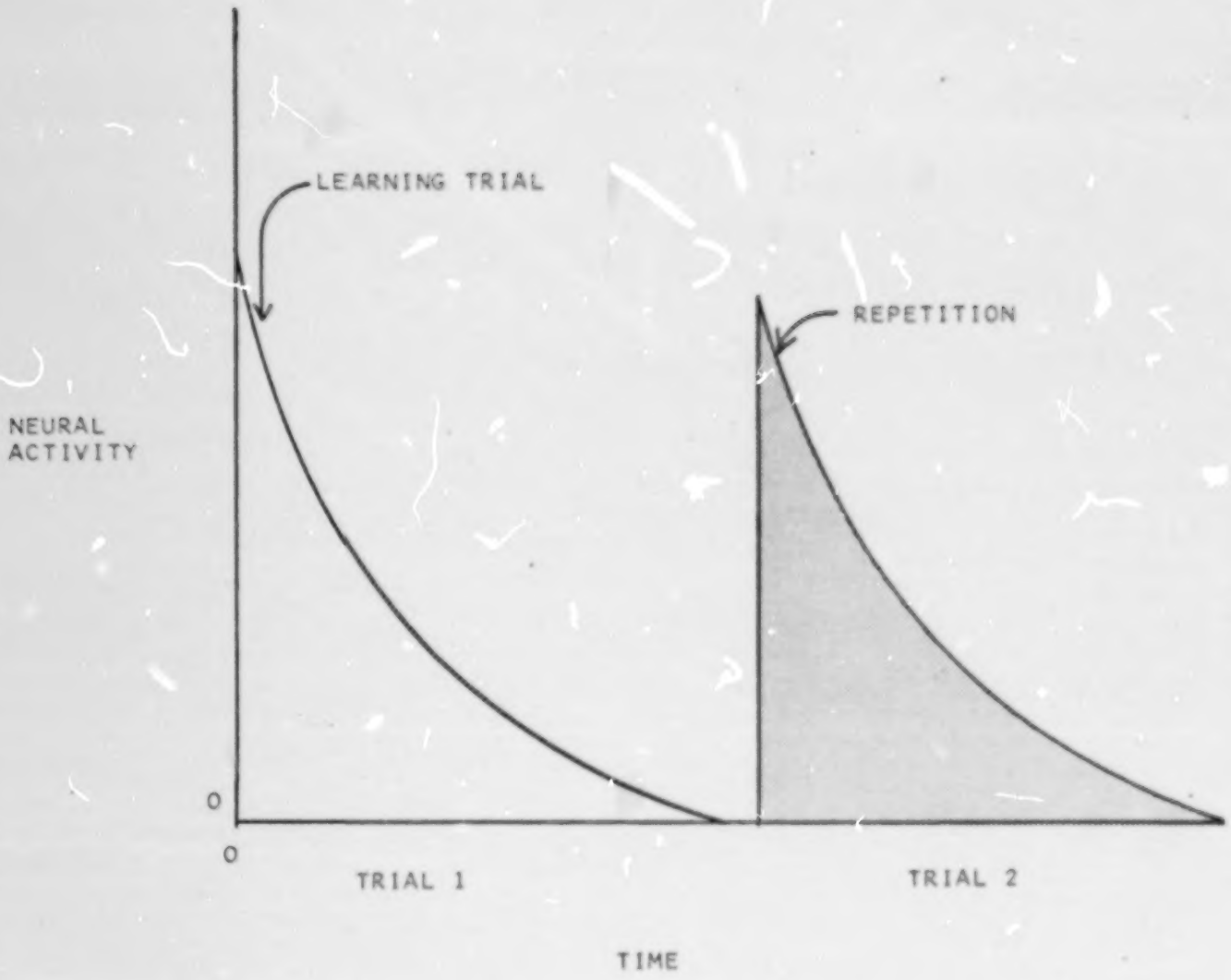

FIGURE 4. EFFECT OF A REPETITION 9(AFTER LANDAUER,1969)

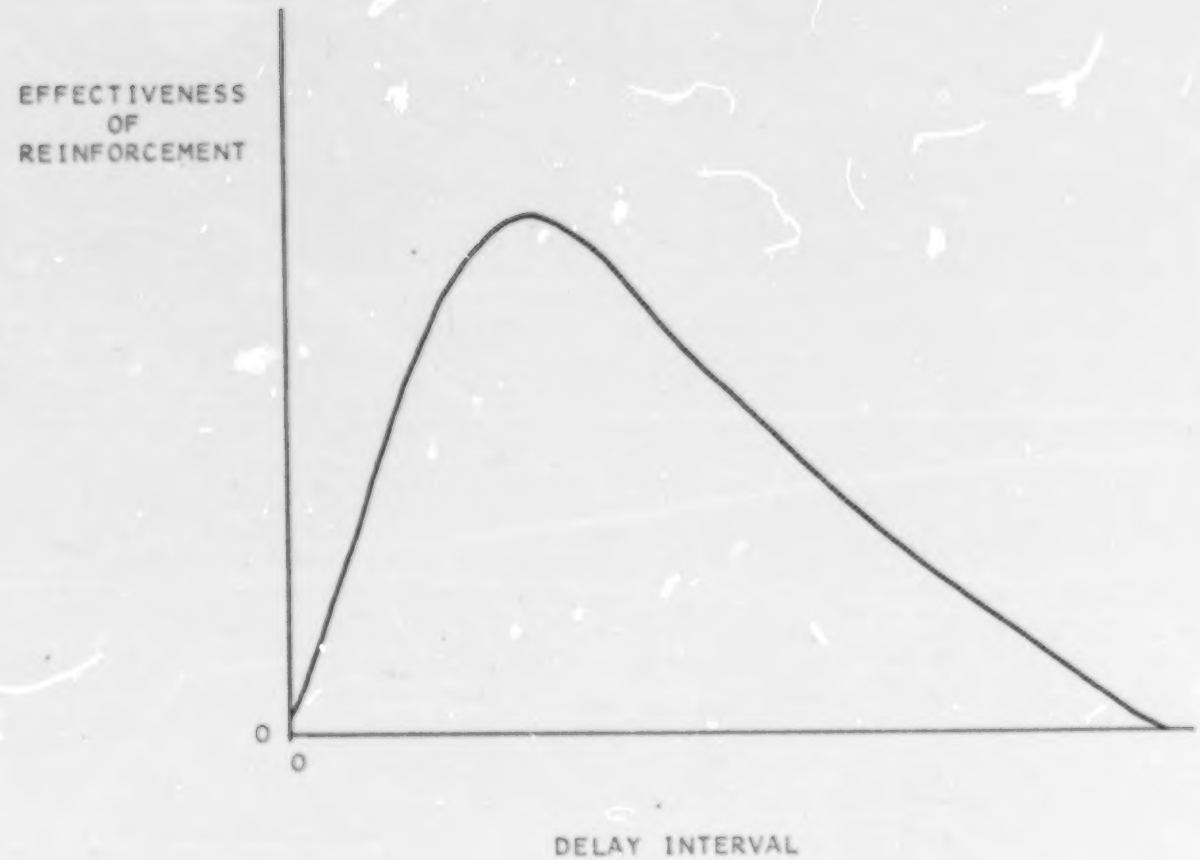

FIGURE 5. DELAY OF REINFORCEMENT CURVE (AFTER LANDAUER, (1969))